Statement of
Dr. Joseph A. Burns
Irving P. Church Professor of Engineering and Astronomy
Vice Provost for Physical Sciences and Engineering
Cornell University, Ithaca, New York 14853

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Mr. Chairman and Members of the Committee:

I appreciate having this opportunity to testify before you today. For most of my professional life, I have been an active planetary scientist and an unabashed enthusiast for space exploration. I chaired the 1994 National Research Council (NRC) strategy for solar system exploration, and more recently I was a member of the NRC's 2003 decadal panel on planetary sciences. I also served as a panel member on the NRC's 2001 decadal report for astronomy and astrophysics.

We meet at a time when, once again, NASA's planetary missions are returning truly remarkable results. For the last three years, the twin *Mars Rovers* have marched systematically across Mars's arid surface, poking their instruments into assorted rocks. These measurements and observations by several superb orbiting spacecraft have revolutionized our perception of the Red Planet, revealing it to have previously been episodically much wetter and perhaps even hospitable to life. *Cassini*, the most recent planetary flagship mission, is orbiting Saturn, where its broad instrument suite has been surveying this ringed beauty for nearly three years, finding that a disparate pair of Saturnian satellites—Titan and Enceladus—are potentially habitable islands in this frigid world. *Stardust*'s capsule has returned samples of comet Wild-2's dust back to Earth and this material has testified about the turbulent nature of the gas/dust cloud that gave birth to our local planetary system. *New Horizons* peeked at Jupiter as it streaked past on its voyage to Pluto. And just last week, a Swiss team spied the 229th extra-solar planet, and a most special one: the first known so far, but for Earth, to reside in its star's habitable zone, where water—life's requisite ingredient—remains fluid. The early 21st century is truly a time of extraordinary discovery in planetary and other space sciences. The continuing generous and unwavering support of Congress and the American people has made these accomplishments possible.

Starting with Sputnik's launch fifty years ago this October, all Earth's peoples—including you and I—have been privileged to participate as our planetary environs have been "*explored, discovered and understood*", to invoke NASA's mantra. Scientists believe that this exploration program addresses profound questions about our origins and that it provides unique insights into how our Earth functions as a planet. At the same time the public finds this investigation of Earth's surroundings to be inspiring and meaningful. January's issue of the popular magazine *Discover* listed its top-ranked one hundred findings across all scientific disciplines during 2006. Of these, fully one-seventh came from astronomy, with half concerning solar system objects or extra-solar planets. So what could be better? The reason why we aren't all celebrating is, because, while America's planetary exploration program is indeed doing well currently, its future is quite uncertain.

I submit to you that an appropriate analogy might be that today's planetary program is like a powerful ship that appears to be staunchly cruising along, making good progress as its crew explores and probes a rich, ever-surprising shoreline. But our vessel is sailing so smoothly nowadays principally because of yesterday's investments. Without continued attention, the ship's momentum will inexorably be drained away. In fact, today's craft is running low on fuel, some of its machines are not being properly maintained and upgraded, improved replacement instruments are unavailable, and sadly the boat's crew is aging. Surprisingly, this ship is from the nation that has always led in exploration of the cosmos. Maybe other nations instead will guide humankind's search of the next shoreline, just as four centuries ago England replaced the Portuguese and the Spanish, partway through the exploration and subsequent development of the New World. Only if we are vigilant today will our ship's journey be secure, with it re-supplied, its instruments revitalized and its crew replaced.

To carry our nautical analogy one step further, fortunately during these treacherous times NASA's Science Mission Directorate has a new admiral—Alan Stern—and the Planetary Science Division has a new captain—Jim Green. These are excellent choices—enthusiastic, knowledgeable and creative scientists who happily are also experienced and successful managers. They will be energetic advocates for—and tireless workers toward—a productive, healthy and effective planetary program.

I now respond to the topics that you have asked me to address. Please note that my ordering is a little different than yours and that many of these items are linked so that my answers to one may overlap with another topic.

Mission mix

Here I will restrict my comments to a consideration of missions; these engineering marvels provide us the capability to *"explore"* as NASA's slogan states. Technology development and research funding will be discussed in later sections.

Planetary science's 2003 decadal survey recommends a finely tuned mix of mission sizes, each with its own programmatic purpose, cost cap and launch rate. *Discovery* missions (e.g., *Deep Impact* that slammed into comet Tempel-1 on July 4, 2005) permit rapid response to discoveries across a range of topics; such missions should launch every eighteen months or so. *New Frontiers* spacecraft (e.g., the *New Horizons* mission en route to Pluto and beyond) allow thorough study of pressing scientific questions, with a selection every two or three years. *Flagship* missions (e.g., the *Cassini* spacecraft presently observing the Saturn system) -- comprehensive investigations of extraordinary high-priority targets -- should be flown at the rate of about one per decade. The separate Mars program has a comparable breakdown of mission classes into large, medium and small (*Mars Scout*) categories.

How do the various missions and their mix fare in the FY08 budget and beyond? The pace of future *Discovery* missions seems about on track, after several years of delayed selections. The *New Frontiers* line has fallen to half the planned rate; the next selection should be made in the next year to get this program back on track.

Once again, no new *Flagships* have been started. The *Europa Geophysical Orbiter* has been indefinitely deferred; it was THE *Flagship* mission recommended for this decade by the decadal study. In fact, at present, no planetary flagship mission is in development, an unprecedented situation that has not happened since the start of the American planetary program. Hence, in view of the necessary preparations and required budget, no major mission will be launched until 2017, and even that schedule will require a significant augmentation to the budget. I am somewhat encouraged that NASA has recently initiated $1M studies of four potential very capable missions to satellites of Jupiter and Saturn; three of these spacecraft would reconnoiter their targets for their suitability to sustain life. Nonetheless it should be recognized that **no** funds are available in the foreseeable future to actually build and fly **any** *Flagship*, if one were to be selected.

Mars flight missions have been reduced from a nominal two launches per opportunity to just one every two years. To accommodate this change, the number of medium-class missions to the Red Planet is lowered, and two *Mars Scouts* are eliminated. In terms of *Flagships*, during the FY 2006 budget-rebalancing exercise, *Mars Sample Return*, a crucial mission to understand the Martian mineralogy and to develop a Martian chronology, was delayed from “early in the next decade” until at least ~2024.

The reining-in of the aspirations of the planetary program is a direct consequence of fewer dollars being available. The agency budget has not grown to accommodate the President’s exploration vision, and so NASA has covered its shortfall by draining $3 B from the science program, 97% of that coming from solar system exploration, especially Mars. Thus the planetary program has become a source of funds to support other demands for NASA’s needs. I am puzzled that NASA would chose to lessen robotic solar system studies, especially investigations of Mars, given the ultimate destination for the President’s vision. The NRC’s Space Studies Board has been steady in its belief that robotic exploration and human exploration are complementary ventures to understand and exploit Earth’s neighbors.

At the time when the American solar system exploration program is slowing down, our international partners (and competitors) are expanding theirs. The European Space Agency has very capable spacecraft orbiting each of Earth’s planetary neighbors, as well as another well-instrumented craft on its way to land on a comet. And soon yet more European spacecraft will be exploring the Moon, where it will join scientific missions from Japan, China and India. Now, when other nations have improved capabilities, we should be pursuing increased interactions with them. However, ITAR regulations hamper international cooperation on existing and planned space missions.

Much of the slowdown in America's exploration of the solar system is not presently apparent because most of pain has been deferred to beyond 2011… to the next administration. But planetary missions require extended advanced planning, especially if we are to collaborate with international partners. For example, the Cassini-Huygens mission to Saturn, on which I am a member, started planning in the early 1980's, selection of payload instruments and team members took place in 1990, launch in 1997, arrival in 2004. Scientific results were not returned until more than twenty years after the mission was initially devised.

The reduced run-out budget for the planetary division, coupled with growth in the cost to mount each of these mission classes, means that the planetary survey's plan is not attainable. New flight projects, especially for outer planet (see below) and Mars exploration, will not be started. The reduction in missions can be painlessly accommodated in the short term because the affected missions occur beyond 2011. However, if the workforce drifts away to other areas and if technology development lags, the loss to the U.S. planetary program will become increasingly irreversible. Analysts suggest that a minimum of at least $200 M more annually would be needed in the PSD budget in order to bring it in line with the strategic plans of the decadal survey.

Research and analysis funds

Now I will address the support for research and analysis (R&A) and technology development. The 2003 planetary survey recommended "an increase over the decade in the funding for fundamental research and analysis programs at a rate above inflation…[till it reaches] closer to 25 % of the overall flight-mission budget." Instead R&A funding has fallen one-quarter from its FY05 level. The budget that you are considering today recommends that this budget line continue to slip further behind the inflation rate, in clear contradiction to the decadal report. Yet it is only through these studies that the American populace "*understands*" the data being returned from Mars, Saturn and other scientific stations.

This continuing decline in R&A funding is troubling for several reasons. Improved understanding and answers motivate our visits to other solar system bodies; to accomplish these goals requires follow-up studies. When funds for supporting research are tight, scientists who are early in their careers are most affected. I know several young scientists who are contemplating career changes because they perceive bleak prospects with space missions. Moreover, any shortfall in the science and engineering workforce will damage the long-term technical and scientific capabilities that underpin the solar system exploration program. Finally, with few academic posts as yet in this emerging discipline and with limited interest to date from the defense/commercial sectors, a higher fraction of the planetary community is supported by soft money than in other astronomical disciplines. Taking a bigger view, I am surprised that NASA's science program has not been considered part of the America's Competitive Initiative, for this program has drawn many to engineering and science as careers.

NASA's goal to *"discover"* becomes somewhat problematic if only limited opportunities exist to analyze mission results. Funding for data analysis should increase in proportion to the growing data volume and the diversity of targets, now including solar wind samples, comet dust, remote-sensing data obtained by dedicated missions at terrestrial and giant planets and measurements taken at academic laboratories.

Top risks for next five years

The future U.S. space enterprise is jeopardized by the loss of core competencies (both technology development and personnel) as a consequence of inadequate base-program resources. Furthermore, the rapid growth in mission costs limits the nature and number of flights that can be flown. Finally the lack of long-lived power sources will prevent missions to the outer solar system.

Monies for technology development are limited. Nonetheless the American planetary program needs more capable instruments to perform more effectively in more difficult environs. For example, dollars could be saved and mission opportunities expanded if in-space advanced propulsion and more efficient radioisotope power systems were available. Future missions will require that samples be returned from inhospitable places and/or that on-site analytical tools be accessible. A healthy funding level would support new instrument development through spaceflight qualification. A limited budget causes a chicken-and-egg problem: present-day funds cannot support both capable missions and the technology that makes those missions as worthwhile as they might be.

Mission costs are rising quickly for several reasons. For some years NASA has been risk-averse and, in today's litigious society, this tendency has only increased. This leads to unnecessary oversight and documentation, with attendant costs, both financial and programmatic. The absence of an adequate technology development program requires either the costly *ab initio* development of new instruments or flying last year's technology. ITAR, which considers satellite technology to automatically be munitions under State Department rules, hamstrings spacecraft operations and complicates international space programs. Expendable launch vehicle costs are growing faster than inflation, because of the limited market. *Discovery* has a separate problem: the imminent phase-out of the Delta-II expendable launch vehicle, which will require future flights to be flown aboard the more-expensive and too-capable EELV (evolved extended launch vehicle) fleet, namely Delta-IVs and Atlas-Vs. Given *Discovery*'s fixed cost cap, substantial increases in launch-vehicle costs erode the science that these missions can achieve.

The usual power supply for missions beyond Jupiter – RTGs containing plutonium-238 – is increasingly scarce, meaning that new starts to outer solar system are no longer feasible. Unless this issue can be resolved to provide power on distant flights, the solar system no longer extends to comet belt, but rather it stops at Jupiter, something similar to halting Henry Hudson at the Azores. This is especially troubling as many of the discipline's highest priority targets –Jovian and Saturnian satellites plus

Neptune/Triton—are very distant. These power generators are also preferred for energy-intensive explorations of Mars.

Especially beneficial strategic investments

Investments in core technologies, science instruments and infrastructure will be most fruitful for the long-term health of the planetary exploration program. Such investments are likely to also benefit other parts of NASA, additional federal agencies that have space platforms and the commercial sector.

The overall budget for solar system exploration should be reinstated so as to allow a continuing reasonable rate of *Discovery* and *New Frontier* flights, but also a new *Flagship* mission, since all classes play important roles in any balanced plan. A sharp increase in R&A funds is essential to a healthy program.

The Human Exploration program needs to be stabilized in order to minimize its potentially adverse impact on science programs. The Shuttle should be retired by 2011 to obviate serious concerns about its safety. Moreover, the operational costs of the Shuttle are eating NASA's lunch (and dinner!).

Place of NASA's proposed lunar science initiative

In spite of the current drought in new mission starts, humankind's exploration of the Moon is reasonably robust, thanks in part to significant international involvement. At the Moon, or soon to be launched, are six lunar missions: four from other nations (Europe, China, Japan and India) as well as a U.S. Lunar Reconnaissance Orbiter and a U.S. Lunar Crater Observation and Sensing Satellite. With this expansion of information about the Moon, it may be time to reassess the adequacy of the current lunar research budget line to benefit fully from the returned results about the surface and interior of Earth's natural satellite.

In addition to these more focused missions, one of the decadal study's recommended *New Frontiers* was to return samples from a deep lunar crater, partly to learn what the lunar interior can tell about the Moon's origin, but also to develop technology that may be deployed at Mars and Venus as well as on comet nuclei. This mission has not yet been selected, but it undoubtedly will be a candidate in the next round. In the more distant future, we have the prospect of human exploration of the moon beginning as early as 2020. All told, these programs form a sustainable initiative of lunar science exploration.

Concluding Remarks

These are exciting times for the planetary program. Unfortunately budgetary constraints are jeopardizing the future of this program. If the United States is to *"explore, discover, understand"* Earth's surroundings, as NASA claims it wishes to do, more attention and additional funding seem to be required. The planetary science community believes that, with Congressional support, and new very capable leaders at the helm of our ship of discovery, our nation's exploration of the solar system will continue to make great progress in understanding our neighboring worlds.

Mr. Chairman and Members of the Committee, I thank you for your attention today, but most of all for your continuing support to NASA's planetary exploration program.

Outline of Joseph A. Burns's remarks to the U.S. House Science Committee 5/2/07

The U.S. planetary program is producing extraordinary scientific results across the solar system as a result of long-term support from Congress. However, the proposed FY08 budget i) is insufficient to allow the mix and pace of flight missions that was recommended by the 2003 planetary decadal survey; ii) should be augmented to support more data analysis; and iii) falls far short of the funds that would adequately strengthen the necessary associated Research and Analysis. The top risks faced by NASA's Planetary Science Division are inadequate funding of technology development, lessened availability of suitable flight and power systems, rising mission costs and the dwindling supply of plutonium to allow missions to the outer solar system. Additional strategic investments in infrastructure, core technologies and scientific personnel would prove especially valuable for the long-term vitality of the U.S. solar system exploration program. The lunar exploration program is reasonably sound, principally because of international missions. Without augmented funding, it is questionable whether NASA will be able to fulfill its stated goal of *"explore, discover, understand."*

Joseph A. Burns

Joseph A. Burns is the Vice Provost for Physical Sciences and Engineering, the Irving Porter Church Professor of Engineering and Professor of Astronomy at Cornell University. Joe received a B.S. from Webb Institute of Naval Architecture in 1962; Cornell awarded his Ph. D. in space mechanics in 1966. In addition to his activities in Ithaca, Burns has held year-long appointments at two NASA facilities (Goddard Space Flight Center and Ames Research Center), at UC-Berkeley and at the University of Arizona. Burns has also spent extended leaves in Moscow, Prague, and Paris. He is a member of the imaging teams for the Cassini (Saturn) and Rosetta (European comet) missions, and was an associate of the Galileo imaging team.

Burns has written more than two hundred papers—both original research and extensive review articles—in the refereed literature. His current research concerns the orbital and rotational evolution of solar system bodies, especially planetary rings and the small bodies of the solar system (dust, satellites, comets and asteroids). Using ground-based telescopes and spacecraft, his students and he have discovered dozens of irregular satellites and several planetary rings.

Burns edited *Icarus*, the principal journal of planetary science, between 1979-1997. He edited two books, Planetary Satellites (1977) and Satellites (1986). He currently sits on the editorial boards of *Science*, *Icarus* and *Celestial Mechanics & Dynamical Astronomy*. Joe has served on many NASA scientific advisory groups and two terms on the Space Studies Board of the National Research Council (NRC), chairing its Committee on Planetary and Lunar Exploration; the latter wrote the NRC's first planetary exploration strategy in 1994. He also sat on the executive committee for the 2003 planetary decadal report and was a panel member for the astronomy community's 2001 decadal strategy. He has been Vice President of the American Astronomical Society; earlier he led its Divisions for Planetary Science (DPS) and on Dynamical Astronomy (DDA). He chairs the International Astronomical Union's Commission on celestial mechanics and dynamical astronomy. Burns is a fellow of the American Geophysical Union and of the AAAS, a member of the International Academy of Astronautics, and a foreign member of the Russian Academy of Sciences. He has received the DPS's Masursky Prize, the USSR's Schmidt medal and several NASA awards for research achievements.

Funding. Professor Burns's current personal research support comes solely from NASA. He has held a Planetary Geology and Geophysics grant for theoretical and dynamical modeling for many years. He is funded as an imaging team member of the Cassini mission at Saturn by the Jet Propulsion Laboratory. These grants pay for two post-doctoral associates and a graduate student, and part of Burns's summer salary. His work as an imaging team member on the European Rosetta comet mission is unfunded. Burns has previously received grants from the NY Council on the Arts, NATO, the National Research Council' Soviet Exchange Program and the NSF. As Vice Provost for Physical Sciences and Engineering, Burns is Cornell's cognizant administrator over about a dozen interdisciplinary research centers, most of whose primary grants are from the NSF.